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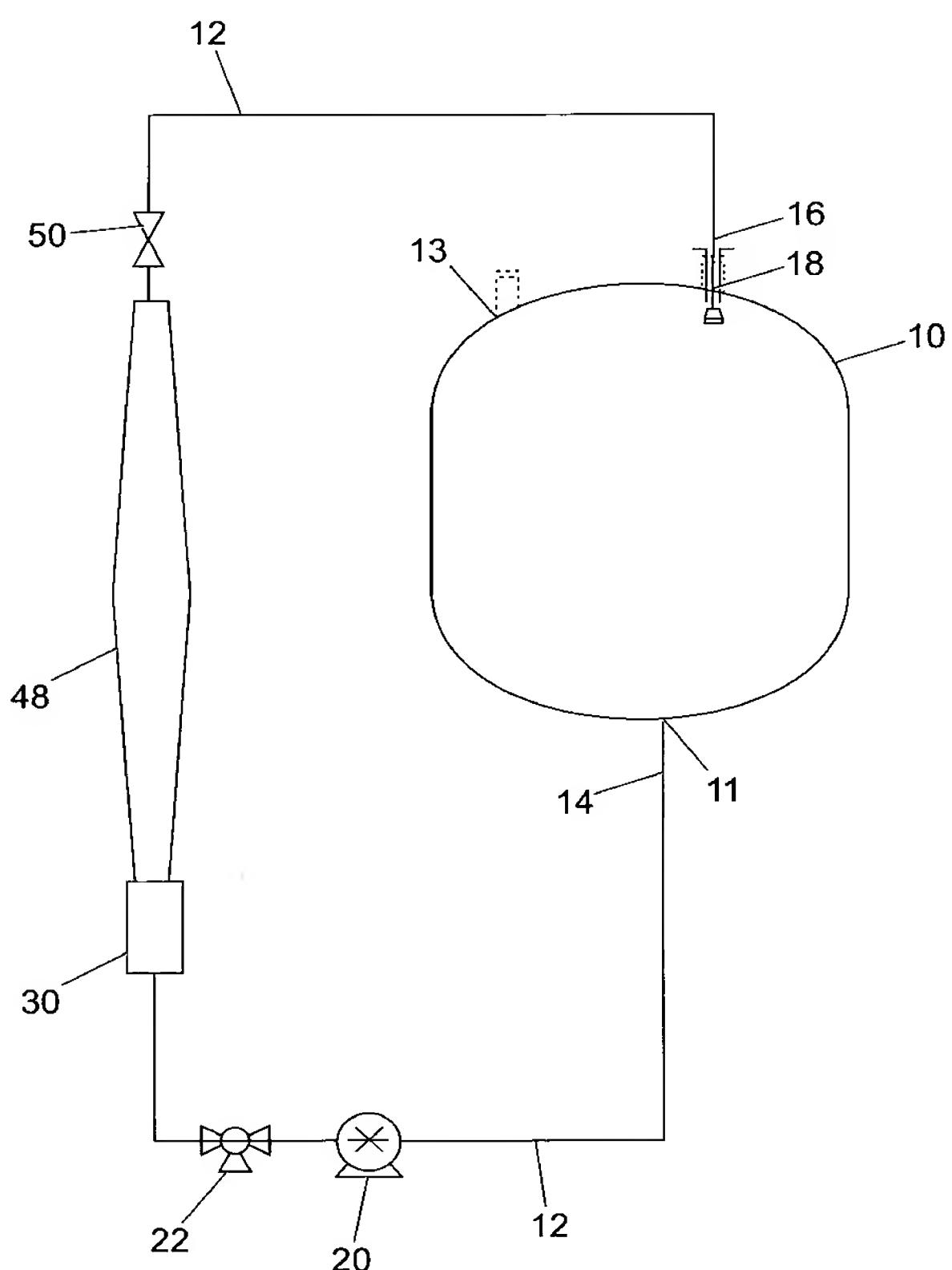
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(54) Title: METHOD AND APPARATUS FOR THE REMOVAL OF VOLATILE ELEMENTS FROM PROCESS FLUIDS



(57) Abstract: An apparatus for the removal of volatile elements from a process fluid is provided. The apparatus comprises at least one steam injector (30) adapted to inject steam into the process fluid and a stripping container (48) adapted to receive process fluid from the steam injector (30). A check valve (50) is located downstream of the stripping container (48) to maintain a predetermined pressure in the stripping container (48). A storage vessel (10) is provided downstream of the stripping container (48) and check valve (50) where the volatile elements separated from the fluid are drawn off. A method of removing the volatile elements from the process fluid is also provided. The apparatus and method of the present invention atomise the process fluid before drawing off the volatile elements, thereby improving the efficiency of the volatile removal process in a number of areas.

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## **METHOD AND APPARATUS FOR THE REMOVAL OF VOLATILE ELEMENTS FROM PROCESS FLUIDS**

This invention relates to the removal of volatile elements from process fluids. More specifically, the invention is a method and apparatus for removing these elements by using direct steam injection. The invention is particularly suited, though not exclusively so, to use in the wort boiling process used in the brewing industry.

There are a large number of applications where it is desirable to remove volatile elements from process fluids. Such elements, also referred to as "volatiles", are often the undesirable by-products of reactions taking place within the fluid. The boiling of wort in brewing is an example of one such application in which it is desirable to remove volatile elements from the wort.

As well as to remove volatile elements from the wort, wort boiling also sterilises the wort and deactivates any enzymes active during the mashing portion of the process. In addition, wort boiling also allows development of colour and taste in the product.

The wort is normally held in kettles prior to the boiling taking place. Conventional wort boiling processes use heat transfer to boil the wort, usually for a period of between 30 and 90 minutes. Whilst the boiling is taking place, the wort is agitated to ensure the contents are evenly treated. The heat transfer can be achieved in a number of ways. For example, in "external wort boiling" a recirculation loop from the kettle is used in order to agitate the wort, and an indirect, or non-contact, heat exchanger located in the loop facilitates the boiling of the wort. Alternatively, in "internal wort boiling" an indirect heat exchanger located in the kettle itself provides the

heat transfer. In another alternative, the kettle can be fitted with an external steam jacket in order to transfer sufficient heat to the contents of the kettle for the boiling.

5 These existing arrangements, which are also used in other fields to evaporate volatile elements, are relatively inefficient at transferring enough heat to the wort for it to achieve a desired temperature. As a result, a great deal of energy is consumed by the arrangements in order to achieve adequate heat transfer. In addition, existing arrangements can be  
10 susceptible to fouling after a certain number of cycles, which necessitates cleaning on a regular basis if the heat transfer is not to become even more inefficient.

15 Additionally, the use of plate heat exchangers in conventional apparatus results in a temperature gradient through the wort or other process fluid. The fluid near the hot surface of the heat exchanger experiences very high temperatures while the fluid some distance away from the hot surface experiences a lower temperature. This results in a non-homogenous heating of the wort.

20 It is an aim of the present invention to obviate or mitigate these disadvantages with existing methods and apparatus for removing volatile elements from process fluids.

25 According to a first aspect of the present invention, there is provided an apparatus for the removal of volatile elements from a process fluid, comprising:  
at least one steam injector adapted to inject steam into the process fluid;

- a stripping container adapted to receive process fluid from the steam injector;
- a storage vessel adapted to receive process fluid from the stripping container; and
- 5 a check valve located between the stripping container and storage vessel and adapted to maintain a predetermined pressure in the stripping container.

Preferably, the steam injector receives process fluid from the vessel.

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Preferably, the steam injector, container and check valve are external of the vessel and connected to the vessel by at least one recirculation conduit. In a preferred embodiment, the apparatus further comprises a pump located on the recirculation conduit.

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Alternatively, the steam injector, container and check valve are located within the vessel.

Preferably, the steam injector comprises:

20

a hollow body provided with a straight-through passage of substantially constant cross-section with an inlet in communication with the vessel and an outlet in communication with the container for the entry and discharge of process fluid;

25

a nozzle having convergent-divergent internal geometry and substantially circumscribing and opening into the passage intermediate the inlet and outlet thereof;

a nozzle inlet adapted to introduce steam to the nozzle; and a mixing chamber located within the passage downstream of the nozzle.

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Preferably, the check valve is a back-pressure valve.

Preferably, the storage vessel is a thermally insulated brewing kettle.

5 In a preferred embodiment, the apparatus comprises a plurality of steam injectors. Most preferably, the plurality of steam injectors are positioned in parallel with one another.

According to a second aspect of the present invention there is provided a  
10 method of removing volatile elements from a process fluid, comprising:

injecting steam into the process fluid in order to raise the temperature of the process fluid to a desired temperature; and

passing the process fluid through a container maintained at a predetermined pressure.

15

Preferably, the method further comprises:

an initial step of filling a storage vessel with a volume of the process fluid prior to the steam injection; and

20 a final step of returning the process fluid to the vessel once it has passed through the container.

Preferably, the steam is injected into the process fluid in a stream which substantially circumscribes the process fluid.

25 Preferably, the steam injection step includes:

atomising the fluid so as to form a dispersed vapour and droplet flow regime; and

boiling the fluid droplets in a low pressure region created by the injection of the steam into the fluid.

30

Preferably, the process fluid is returned to the vessel from the container at atmospheric pressure.

Preferably, the process fluid is brewing wort.

5

Preferably, the application of the injection of steam is continuous.

Preferably, the pressure maintained in the container is less than 100 kPa (1 bar).

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A preferred embodiment of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

15

Figure 1 is a schematic view of an apparatus for removing volatile elements from a process fluid; and

Figure 2 is a cross-sectional view of a steam injector used in the apparatus of Figure 1.

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An apparatus for removal of volatile elements from a process fluid is shown in Figure 1. For the purposes of the description, the apparatus is described when in use in a wort boiling process during brewing. However, it should be appreciated that the present invention is not limited to this wort boiling application alone.

25

The apparatus shown in Figure 1 comprises an insulated kettle 10 having a vent stack 13, and a fluid outlet 11 and fluid inlet 18. The outlet 11 and inlet 18 are connected together by a pipework recirculation loop 12. A first end 14 of the loop 12 is connected to the outlet 11, whilst a second end 16

of the pipework is connected to the inlet 18. A pump 20 is provided on the loop 12, as well as a drain/fill valve 22.

A steam injector 30 is also located on the loop 12. As can be seen in 5 Figure 2, the steam injector 30 comprises a housing 32 defining a passage 33 providing an inlet 34 and an outlet 35. The passage 33 is of substantially constant circular cross section. The housing 32 contains a plenum 38 for the introduction of steam, the plenum 38 being provided with an inlet 39. The distal end of the plenum 38 is tapered and defines an 10 annular nozzle 40. The nozzle 40 is in flow communication with the plenum 38 and is of a convergent-divergent internal geometry. In other words, the nozzle has an intermediate portion located between a nozzle inlet and a nozzle outlet, and the intermediate portion has a cross 15 sectional area which is smaller than that of either the nozzle inlet or nozzle outlet. Connected to the downstream end of the steam injector 30 is an elongate stripping container 48 with a check valve, shown here in the form of a back-pressure valve 50, situated downstream of the container 48. Where the term "stripping container" is used in this specification, it should 20 be understood that this term is intended to encompass any container suitable for use in removing volatile components from a process fluid.

The operation of the apparatus will now be described with reference to both Figures 1 and 2. Initially, a process fluid, which in this example is brewing wort, is introduced into the apparatus via the drain/fill valve 22 25 under the action of an external pump (not shown). The wort is continually pumped into the apparatus until the system is filled to capacity. Once the drain/fill valve 22 is closed, the internal pump 20 is switched on and begins to pump wort from the kettle 10 into the recirculating loop 12. Alternatively, the pump 20 is switched on once a predetermined volume of 30 wort is introduced into the system and pumps wort into the loop 12 whilst

the system is still filling. In either case, the wort drawn into the loop 12 will first enter the steam injecting apparatus 30, the operation of which is illustrated in Figure 2. This phase is known as the “pre-boil” phase, and will continue until such time as the wort in the kettle 10 reaches a rolling 5 boil at the desired temperature.

The inlet 34 of the steam injector 30 receives the wort pumped from the kettle 10. Introduction of steam into the injector 30 through the steam inlet 39 and plenum 38 causes a jet of steam to issue forth through the nozzle 10 40. Due to the configuration of the nozzle 40, the stream of steam being injected circumscribes the wort passing through the injector 30. The steam interacts with the wort in a section of the passage 33 operating as a mixing chamber 36.

15 The steam jet issuing from the nozzle 40 occasions induction of the wort through the passage 33, which because of its straight through axial path and lack of any constrictions provides a substantially constant dimension bore which presents no obstacle to the flow. The steam injection creates a low pressure region in the mixing chamber 36 downstream of the nozzle 20 40. The parametric characteristics of the steam coupled with the geometric features of the nozzle, upstream wall profile and mixing chamber are selected for optimum energy transfer from the steam to the wort. The first energy transfer mechanism is momentum and mass transfer which results in atomisation of the wort. This energy transfer 25 mechanism is enhanced through turbulence. Figure 2 shows diagrammatically the break-up, or atomisation 45 of the wort prior to its entry into the container 48.

30 The steam enters through nozzle 40 at supersonic velocity. The wort flows at a subsonic velocity into the inlet 34. As the steam exits the nozzle

40 it exhibits local shock and expansion waves and forms a pseudo vena contracta. The accelerated region of dispersion (or dissociation) of the wort flows at a locally supersonic velocity into the atomisation region 45, in which the vapour is predominantly steam and the droplets are  
5 predominantly the wort.

It is the acceleration of the steam through the convergent-divergent portion of the nozzle 40 which allows the steam to reach supersonic velocity. As a result of this acceleration, the steam is injected with high energy but at  
10 relatively low temperature (typically 70-85°C). For example, the steam can be injected through the nozzle with a pressure of 6bär but it will have an initial temperature of only 80°C when contacting the process fluid thanks to the low pressure area formed adjacent the nozzle outlet. Initially, the energy transfer between the steam and the wort is in the form  
15 of kinetic energy as the steam imparts shear forces on the wort. As the wort moves along the mixing chamber 36 its velocity reduces, and the kinetic energy imparted by the steam changes to heat energy. The low pressure region created in the mixing chamber allows the wort to boil at lower temperatures than would be possible in standard atmospheric  
20 conditions. Therefore, the heat energy transfer caused by the slowing down of the wort causes the temperature of the wort to homogenously rise until it reaches its local boiling point in the low pressure region. This boiling allows product to boil off, thereby separating volatile elements from the remainder of the wort.

25 As can also be seen in Figure 2, the container 48 is immediately downstream of the steam injector 30 and in fluid communication with the mixing chamber 36 thereof. In the preferred embodiment illustrated, the container 48 is elongate and lies on a substantially vertical axis. The  
30 container 48 has a significantly larger diameter than the mixing chamber

36 and is consequently of much larger volume. The container 48 has a volume which is at least five times greater than the mixing chamber. In testing, it has been established that the preferred ratio of volume between the mixing chamber 36 and container 48 is 1:250.

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A multi-phase flow comprising uncondensed steam, vaporised volatile elements and the wort droplets formed in the mixing chamber 36 enters the container 48 as a turbulent vapour-droplet regime. The container 48 allows the uncondensed steam which has not been absorbed by the wort further time in which to be absorbed. The uncondensed steam also increases turbulence in the container 48, thereby assisting in the stripping of the volatile components from the wort. The container 48 allows the wort to be held at an elevated pressure and temperature (e.g. c.109°C) which also increases the rate of reaction therein. Any volatiles stripped from the wort are prevented from condensing due to the elevated pressure and temperature, and are carried downstream through the loop 12 back into the kettle 10, from where they are vented through the vent stack 13.

10

The back pressure valve 50 downstream of the container 48 allows the container 48 to be held at an elevated pressure of up to 100 kPa (1 bar).

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The valve 50 places a restriction in the loop 12 which elevates the pressure in the container 48 but still allows fluid flow back to the kettle 10.

Downstream of the back pressure valve 50, the loop 12 is at atmospheric pressure. As the wort passes through the valve 50, the drop in pressure

20

instantaneously vaporises any volatile components remaining in the wort.

In order to still further improve the performance of the apparatus, it is preferable to have the back-pressure valve 50 located as close to the kettle inlet 14 as possible. In this way, the vaporised volatile elements have little time to condense again before they are drawn up through the

25

vent stack 13.

30

The present invention has a number of advantages over conventional apparatus for removing volatiles. There is a much more efficient and homogenous transfer of heat, via the change from kinetic energy to heat energy, thanks to the direct steam injection. Thanks to the atomisation of the process fluid, the surface area of the fluid is greatly increased, which means more of the fluid is directly exposed to the heat. This consequently reduces the amount of energy required to condition the process fluid compared with the heat exchangers and calandria used in known apparatus. In addition, the generation of a low pressure region in the steam injector allows the process fluid to be locally boiled at lower than normal temperatures. Thus, even less energy is consumed in the boiling process.

15 The present invention also significantly reduces the time taken for the boiling process to begin. In the “pre-boil” phase of conventional apparatus, the boiling cannot begin until the heat exchanger is filled with process fluid. This typically requires between 50-75% of the volume of the kettle to enter the heat exchanger. With the present invention, the boiling process can start far more quickly, with typically only 1-10% of the process fluid in the apparatus.

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Thanks to the arrangement of the container and back-pressure valve, the stripping of the volatile components from the process fluid is more efficient than in conventional apparatus. The container ensures that the uncondensed steam adds to the turbulent flow, whilst the back pressure valve ensures instant vaporisation of any remaining volatiles. Furthermore, thanks to the container maintaining the elevated temperatures therein, the rate of reaction of the process fluid is also significantly improved. Additionally, by atomising the process fluid in the

steam injector, the apparatus also ensures that no volatile elements are trapped in the process fluid, as can happen during a conventional boil process.

5 The steam injector of the present invention also ensures that controlled heating of the process fluid is achieved. This is particularly beneficial in the food and drink processing industry where the burning of the product must be avoided. By conditioning the steam so that it is injected with high energy and low temperature, and by homogenously heating the product, 10 the risk of burning the product which is first contacted by the steam is removed. Were the steam to be injected at a conventional pressure and temperature (e.g. 1 bar pressure and 109°C), the process fluid would be subjected to a temperature shock in which a significant percentage of the product would likely be burnt.

15 The controlled heating and avoidance of burning also reduces the possibility of the apparatus fouling. In conventional heat exchangers, the portion of the process fluid in the heat exchanger which is closest to the heat source can burn if the heat is increased to ensure that all of the 20 product is properly heated. This “burn-on” of the product can lead to the fouling of the heat exchanger. There is also a reduced possibility of fouling with the present invention because the steam injector has a straight-through passage of substantially constant diameter and no moving parts. Furthermore, the invention does not require the added expense and 25 complexity of condensate return systems which are needed in indirect heat exchangers.

30 The present invention also has a number of advantages when utilised in the brewing industry, and specifically in the wort boiling process used therein. Firstly, the present invention can enhance boiling at high altitude.

In breweries situated at high altitude the process fluids will boil at a lower temperature than they would at sea level. By maintaining an elevated pressure in the container of the present invention, the temperature of the process fluid can be raised such that the boiling point of the fluid at altitude 5 matches the boiling point at sea level. This elevation of pressure and temperature enhances reaction rates during the wort boiling process.

The steam injector of the present invention allows enhanced flavour extraction during the wort boiling process. This is thanks to the creation 10 of the low pressure region in the passage through which the atomised process fluid passes. As the fluid passes through the low pressure region, cellular material (e.g. hops) contained therein expands and creates gaps through which the vapours can pass. Thus, as the vapours are passing over more exposed surfaces of the cellular material, more flavours are 15 extracted from the material as the processing takes place.

A further benefit of the present invention in the brewing industry is that the build up of "slugs" or balls within the brewing vessel is prevented. In a conventional brewing process, powdered additives such as sugars and 20 flavour enhancers can be introduced during the wort boiling process. These powders can ball up within the vessel and may not properly mix with the process fluid. Thanks to the high shear forces imparted on the process fluid by the steam injector of the apparatus, these balls of powder are at worst broken up and in most instances are actually prevented from 25 forming at all.

Whilst the preferred embodiment of the invention described above only comprises a single steam injector, an array formed from a plurality of steam injectors may also be incorporated into the apparatus. In such an

instance, the injectors would preferably be arranged in parallel with one another in the recirculation loop.

The vessel may also include a spreader in order to help reduce foaming of  
5 the process fluid and assist in the stripping process. The spreader is normally cone-shaped and diverts the returning process fluid around the vessel. With the turbulent flow within the apparatus, the fluid returns with sufficient force that it can bounce off the spreader onto the walls of the vessel. By running down the vessel walls, the foaming of the fluid in the  
10 vessel is reduced.

As an alternative to the recirculation loop, the apparatus of the present invention can also be located directly in the kettle. In this alternative embodiment, the steam injector, container and back-pressure valve would  
15 be connected in series within the kettle. The drain/fill valve of the preferred embodiment can be replaced with any other conventional filling apparatus.

Whilst the preferred embodiment of the invention described above is a  
20 closed-loop batch arrangement, the present invention may also be used in-line as part of a larger process. In such an instance the process fluid would not be cycled around the apparatus. Instead, the steam injector would receive process fluid from a remote location and the storage vessel would allow volatile gases to be drawn off before the fluid proceeds to the  
25 next part of the process line.

The check valve described in the preferred embodiment can be either a manually or automatically adjusted valve. In the case where the valve is automatic, a suitable sensor and electronic control module arrangement  
30 can be incorporated to monitor one or more variables within the container.

While the fluid container has been described as being elongate and substantially vertical, it should be understood that the invention is not limited to use of such a container. So long as the container can hold a 5 volume of process fluid which is in accordance with the previously described volume ratios between steam injector mixing chamber and container, other shapes of container may be possible. A preferred alternative container is spherical, for example.

10 As already explained above, whilst the preferred embodiment of the invention described above is concerned with use in the boiling of wort as part of a brewing process, those skilled in the art will appreciate that the apparatus and method of the present invention may also be applied in other areas where the removal of volatile elements from process fluids is 15 required. As well as the food and drink processing applications already described, other examples of such areas are the removal of harmful chemicals from slurries of contaminated soils, and fractional distillation used in the production of ethanol. To adapt the apparatus of the present invention for use in these other areas, the only change of significance 20 would be to replace the kettle with an alternative fluid storage vessel having the desired specification.

It should also be recognised that the apparatus and method can be used in certain applications where volatile elements may be vaporised without 25 the process fluid necessarily reaching its boiling point. Accordingly, instances in the foregoing description which describe the boiling of the process fluid are to be understood as non-limiting examples.

These and other modifications and improvements may be incorporated 30 without departing from the scope of the invention.

**CLAIMS:**

1. An apparatus for the removal of volatile elements from a process fluid, comprising:
  - 5 at least one steam injector adapted to inject steam into the process fluid;
  - a stripping container adapted to receive process fluid from the steam injector;
  - a storage vessel adapted to receive process fluid from the stripping container; and
  - 10 a check valve located between the stripping container and storage vessel and adapted to maintain a predetermined pressure in the stripping container.
- 15 2. The apparatus of Claim 1, wherein the steam injector receives process fluid from the storage vessel.
3. The apparatus of Claim 2, wherein the steam injector, stripping container and check valve are located within the vessel.
- 20 4. The apparatus of Claim 2, wherein the steam injector, stripping container and check valve are external of the vessel and connected to the vessel by at least one recirculation conduit.
- 25 5. The apparatus of Claim 1, wherein the apparatus is adapted to form part of a process line, wherein the steam injector is adapted to receive process fluid from an upstream section of the process line and the storage vessel is adapted to pass process fluid to a downstream section of the process line.

6. The apparatus of any of Claims 2 to 5, wherein the storage vessel is a thermally insulated brewing kettle.

5 7. The apparatus of any preceding claim, further comprising a pump adapted to pump the process fluid through the apparatus.

8. The apparatus of any preceding claim, wherein the steam injector comprises:

10 a hollow body provided with a straight-through passage of substantially constant cross-section with an inlet in communication with the vessel and an outlet in communication with the stripping container for the entry and discharge of process fluid;

a nozzle having convergent-divergent internal geometry and opening into the passage intermediate the inlet and outlet thereof;

15 a nozzle inlet adapted to introduce a supply of steam to the nozzle; and

a mixing chamber located within the passage downstream of the nozzle.

20 9. The apparatus of any preceding claim, wherein the check valve is a back-pressure valve.

10. The apparatus of any preceding claim, comprising a plurality of steam injectors.

25 11. The apparatus of Claim 10, wherein the plurality of steam injectors are positioned in parallel with one another.

30 12. A method of removing volatile elements from a process fluid, comprising:

injecting steam into the process fluid in order to atomise the process fluid and form a vapour-droplet regime;

passing the vapour-droplet regime through a low pressure region in which volatile elements within the process fluid are vaporised;

5           passing the vapour-droplet regime through a stripping container maintained at an elevated pressure in order to vaporise any remaining volatile elements within the process fluid; and

              condensing the vapour-droplet regime of the processing fluid and drawing off any volatile vapours.

10

13.   The method of Claim 12, further comprising:

              an initial step of filling a storage vessel with a volume of the process fluid prior to the steam injection; and

              a final step of returning the condensed process fluid to the vessel.

15

14.   The method of Claim 13, wherein the process fluid is returned to the vessel from the stripping container at atmospheric pressure.

15.   The method of Claim 13 or Claim 14, wherein the volatile vapours  
20        are drawn off in the storage vessel.

16.   The method of any of Claims 12 to 15, wherein the steam is injected into the process fluid in a stream which substantially circumscribes the process fluid.

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17.   The method of any of Claims 12 to 16, wherein the process fluid is brewing wort.

18.   The method of any of Claims 12 to 17, wherein the injection of  
30        steam is continuous.

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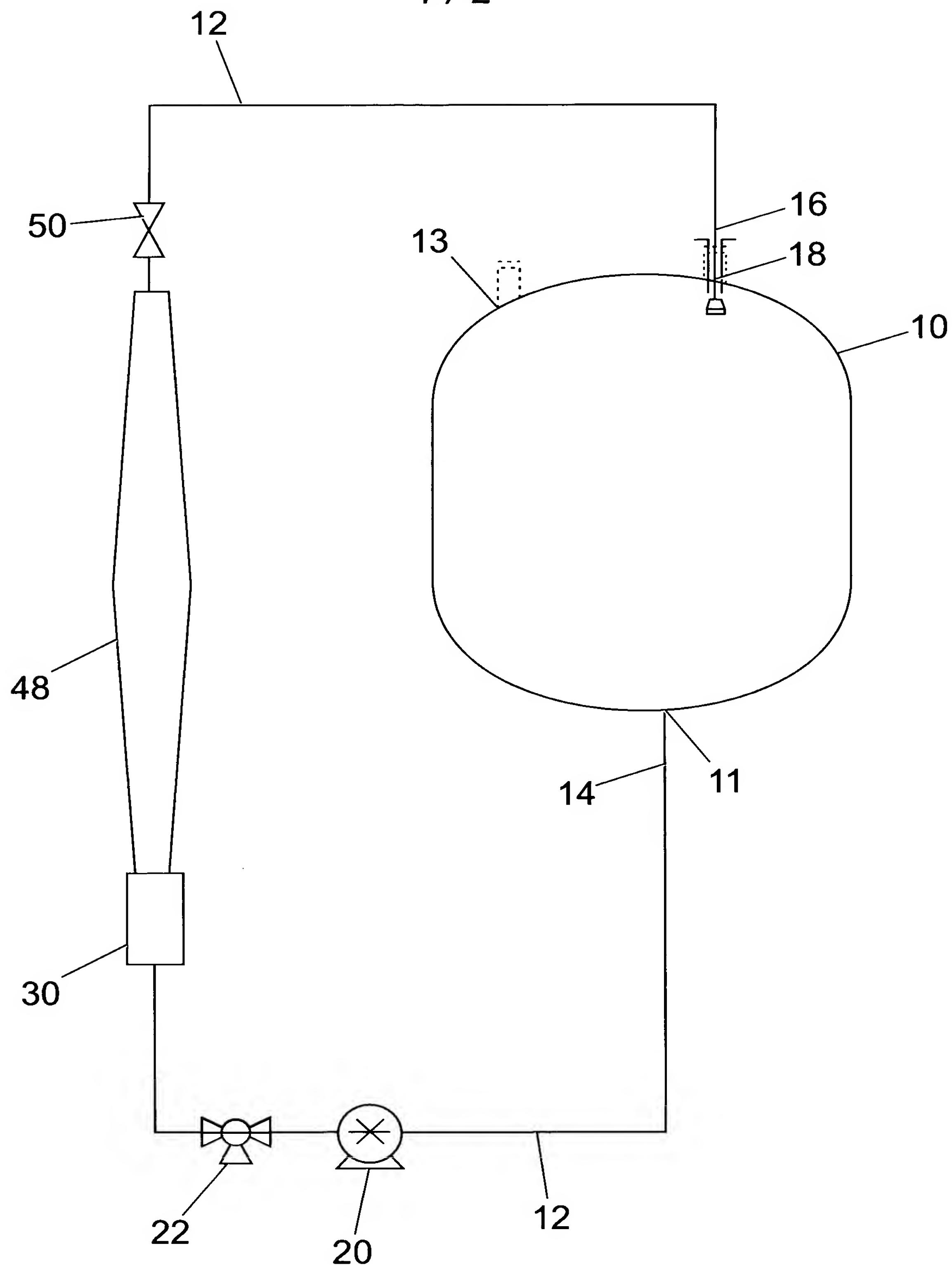


Fig. 1

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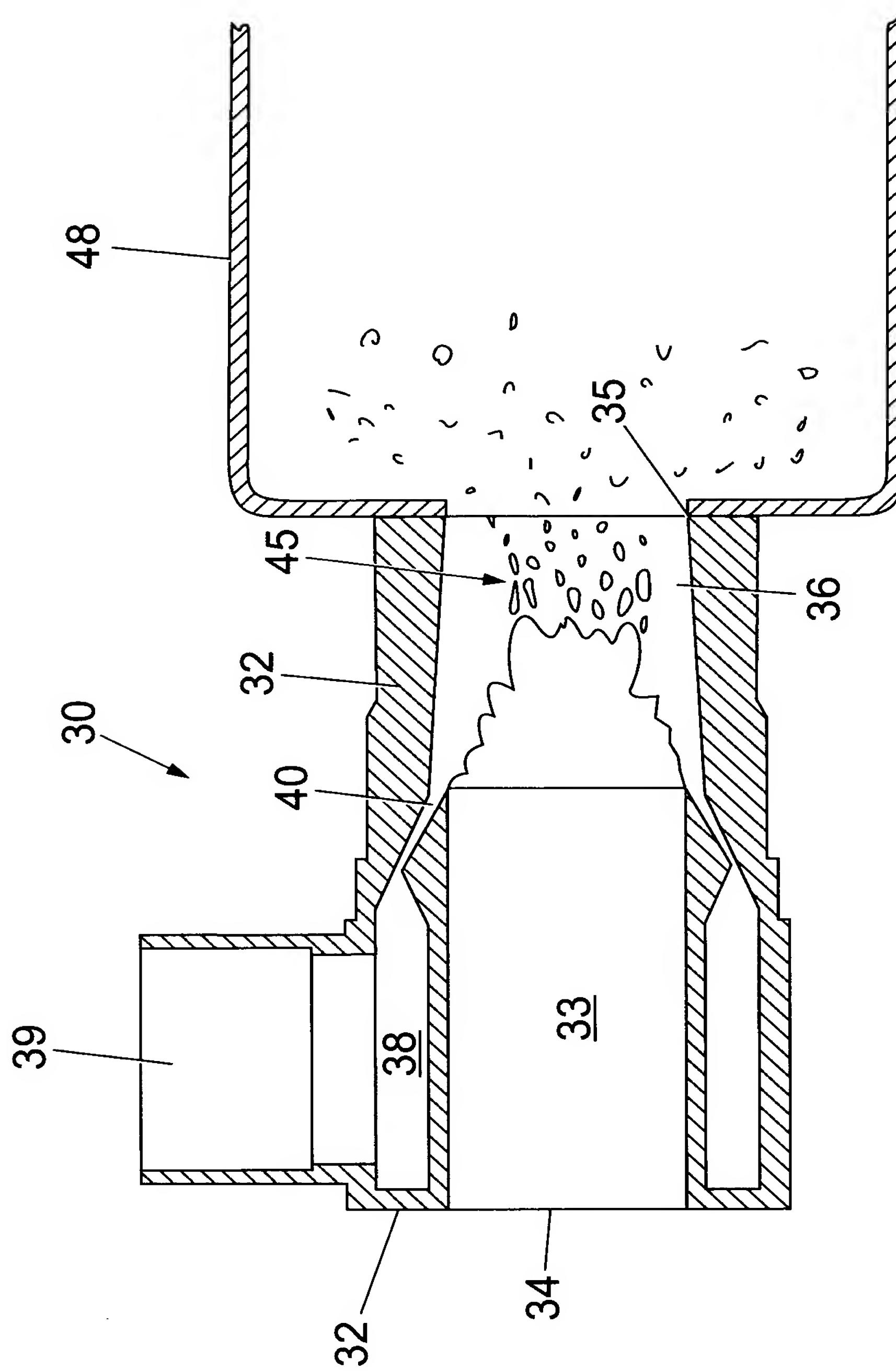


Fig. 2

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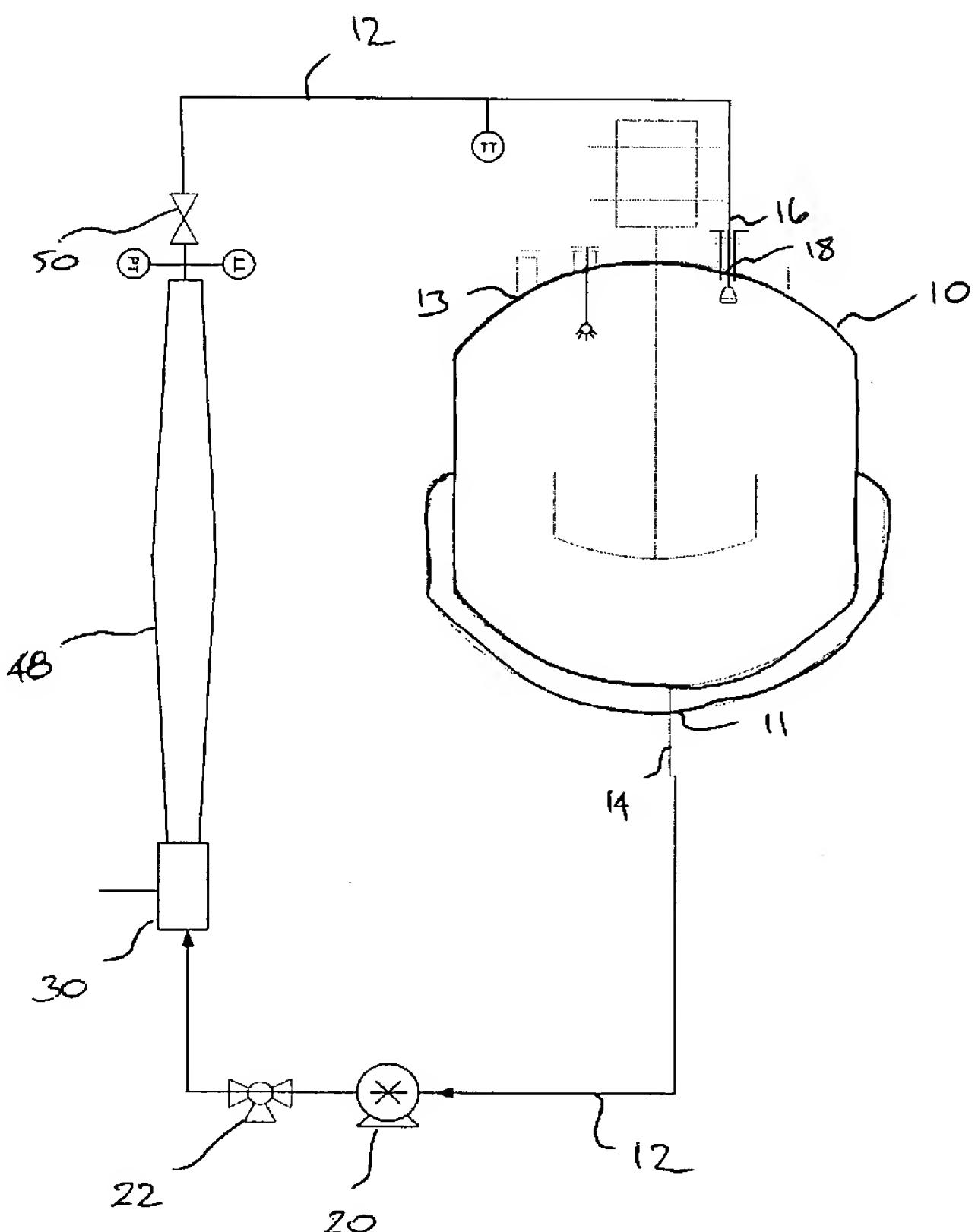
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**(54) Title: METHOD AND APPARATUS FOR THE REMOVAL OF VOLATILE ELEMENTS FROM PROCESS FLUIDS**



**(57) Abstract:** An apparatus for the removal of volatile elements from a process fluid is provided. The apparatus comprises at least one steam injector (30) adapted to inject steam into the process fluid and a stripping container (48) adapted to receive process fluid from the steam injector (30). A check valve (50) is located downstream of the stripping container (48) to maintain a predetermined pressure in the stripping container (48). A storage vessel (10) is provided downstream of the stripping container (48) and check valve (50) where the volatile elements separated from the fluid are drawn off. A method of removing the volatile elements from the process fluid is also provided. The apparatus and method of the present invention atomise the process fluid before drawing off the volatile elements, thereby improving the efficiency of the volatile removal process in a number of areas.



FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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A. CLASSIFICATION OF SUBJECT MATTER  
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## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
B01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2005/011355 A1 (WILLIAMS WILLIAM ROBERT [US] ET AL) 20 January 2005 (2005-01-20) abstract; figures page 1, paragraph 17 - paragraph 19 page 2, paragraphs 27, 29	1-11
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 Further documents are listed in the continuation of Box C. See patent family annex.

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## C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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